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WHITE LAKE, MUSKEGON COUNTY, MICHIGAN

Pacific Northwest Environmental Research Laboratory

Prepared for:

National Environmental Research Center
Michigan Department of National Resources
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16. ABSTRACT
Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivded according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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REPORT
ON
WHITE LAKE
MUSKEGON COUNTY
MICHIGAN

EPA REGION V

WORKING PAPER No. 217

WITH THE COOPERATION OF THE

MICHIGAN DEPARTMENT OF NATURAL RESOURCES

AND THE

MICHIGAN NATIONAL GUARD

MARCH, 1975

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to fresh water lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Michigan Department of Natural Resources for professional involvement and to the Michigan National Guard for conducting the tributary sampling phase of the Survey.

A. Gene Gazlay, former Director, and David H. Jenkins, Acting Director, Michigan Department of Natural Resources; and Carlos Fetterolf, Chief Environmental Scientist, and Dennis Tierney, Aquatic Biologist, Bureau of Water Management, Department of Natural Resources, provided invaluable lake documentation and counsel during the course of the Survey. John Vogt, Chief of the Bureau of Environmental Health, Michigan Department of Public Health, and his staff were most helpful in identifying point sources and soliciting municipal participation in the Survey.

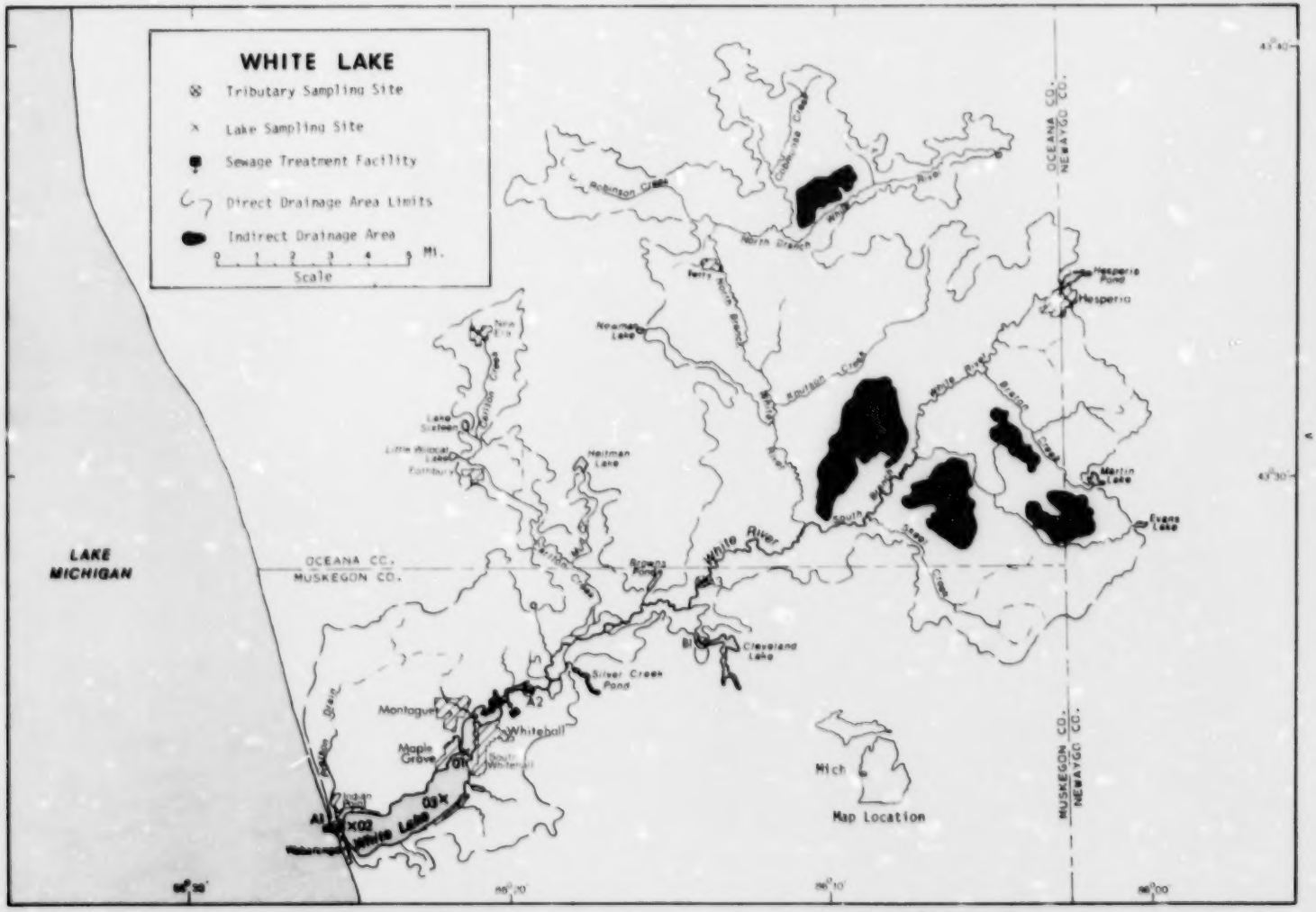
Major General Clarence A. Schnipke (Retired), then the Adjutant General of Michigan, and Project Officer Colonel Albert W. Lesky, who directed the volunteer efforts of the Michigan National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF MICHIGAN

LAKE NAME	COUNTY
Allegan Res.	Allegan
Barton	Kalamazoo
Belleville	Wayne
Betsie	Benzie
Brighton	Livingston
Caro Res.	Tuscola
Charlevoix	Charlevoix
Chemung	Livingston
Constantine Res.	St. Joseph
Crystal	Montcalm
Deer	Marquette
Ford	Washtenaw
Fremont	Newago
Higgins	Roscommon
Holloway Res.	Genesee, Lapeer
Houghton	Roscommon
Jordon	Ionia, Barry
Kent	Oakland
Long	St. Joseph
Macatawa	Ottawa
Manistee	Manistee
Mona	Muskegon
Muskegon	Muskegon
Pentwater	Oceana
Pere Marquette	Mason
Portage	Houghton
Randall	Branch
Rogers Pond	Mecosta
Ross	Gladwin
St. Louis Res.	Gratiot
Sanford	Midland
Strawberry	Livingston
Thompson	Livingston
Thornapple	Barry
Union	Branch
White	Muskegon


WHITE LAKE
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
Direct Drainage Area Limits
Indirect Drainage Area
0 1 2 3 4 5 Mi.
Scale
LAKE MICHIGAN
OCEANA CO.
MUSKEGON CO.
OCEANA CO.
NEWAYGO CO.
MUSKEGON CO.
NEWAYGO CO.
White River
South Branch White River
North Branch White River
Robinson Creek
Cedar Creek
Duncan Creek
Stanton Creek
Hesperia
Hesperia Pond
Newaygo Lake
Lake Sixteen
Little Round Lake
Farnsworth
Holman Lake
Bigelow Pond
Silver Creek Pond
Cleveland Lake
Martin Lake
Evans Lake
Montague
Whitehall
Maple Grove
White Lake
Mich
Map Location
43°40'
43°30'
86°30'
86°20'
86°10'
86°00'

WHITE LAKE

STORET NO. 2688

I. CONCLUSIONS

A. Trophic Condition:

Survey data and the records of others (Robinson et al., 1967) show that White Lake is eutrophic. Of the 35 Michigan lakes sampled in November when essentially all were well-mixed, nine had less mean total phosphorus, 12 had less mean dissolved phosphorus, and 11 had less mean inorganic nitrogen; of all 41 lakes sampled, six had greater Secchi disc transparency, and eight had less mean chlorophyll a*. Marked depression of dissolved oxygen at and below 27 feet occurred at stations 2 and 3 in September, 1972.

Ketelle and Uttormark (1971) reported that excessive algal and aquatic weed growths occur regularly in White Lake.

B. Rate-Limiting Nutrient:

There was a significant loss of phosphorus in the algal assay sample, and the results are not representative of conditions in the lake at the time the sample was taken. The lake data indicate nitrogen limitation in June and September but phosphorus limitation in November.

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* See Appendix A.

C. Nutrient Controllability:

1. Point sources--During the sampling year, White Lake received a total phosphorus load at a rate about 1.5 times the rate proposed by Vollenweider (in press) as "dangerous"; i.e., a eutrophic rate (see page 11). However, White Lake has a relatively short mean hydraulic retention time of 56 days, and Vollenweider's model may not be applicable.

The City of Whitehall no longer impacts White Lake, and the other point sources considered in this report either have or soon will terminate their discharges (Bastian, 1974).

It is calculated that elimination of these discharges will reduce the phosphorus loading rate to 14.6 lbs/acre/yr or 1.64 $g/m^2/yr$. While this rate will still exceed the eutrophic rate, in view of the short hydraulic retention time and the questionable applicability of Vollenweider's model, it is believed the lower loading rate will at least reduce the incidence and severity of nuisance algal blooms as well as provide additional protection for Lake Michigan.

2. Non-point sources (see page 11)--During the sampling year, the phosphorus export of the White River was somewhat high as compared to the exports of Michigan streams studied elsewhere. This relatively high export and the export N/P ratio indicate a possible point source in the drainage beyond the 25-mile limit of the Survey*.

* See Working Paper No. 1, "Survey Methods, 1972".

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

A. Lake Morphometry†:

1. Surface area: 2,571 acres.
2. Mean depth: 22.5 feet.
3. Maximum depth: 70+ feet.
4. Volume: 57,940 acre-feet.
5. Mean hydraulic retention time: 56 days.

B. Tributary and Outlet:
(See Appendix B for flow data)

1. Tributaries -

Name	Drainage area*	Mean flow*
White River	481.0 mi^2	495.1 cfs
Minor tributaries & immediate drainage -	24.0 mi^2	27.2 cfs
Totals	505.0 mi^2	522.3 cfs

2. Outlet -

White River	509.0 mi^2**	522.3 cfs

C. Precipitation***:

1. Year of sampling: 31.0 inches.
2. Mean annual: 31.4 inches.

---

† Robinson, Cosens, & Mills, 1967.
* Drainage areas are accurate within ±5%; mean daily flows for 74% of the drainage areas are accurate within ±25% and the remaining sites up to ±40%; and mean monthly flows, normalized mean monthly flows, and mean annual flows are slightly more accurate than mean daily flows.
** Includes area of lake.
*** See Working Paper No. 1, "Survey Methods, 1972".

III. LAKE WATER QUALITY SUMMARY

White Lake was sampled three times during the open-water season of 1972 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from three stations on the lake and from two or more depths at each station (see map, page v). During each visit, a single depth-integrated (15 feet to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the second visit, a single five-gallon depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 21 feet at station 1, 54 feet at station 2, and 34 feet at station 3.

The results obtained are presented in full in Appendix C, and the data for the fall sampling period, when the lake essentially was well-mixed, are summarized below. Note, however, the Secchi disc summary is based on all values.

For differences in the various parameters at the other sampling times, refer to Appendix C.

A. Physical and chemical characteristics:

Parameter	Minimum	Mean	Median	Maximum
		FALL VALUES (11/14/72)		
Temperature (Cent.)	6.9	7.0	7.0	7.1
Dissolved oxygen (mg/l)	10.2	10.3	10.4	10.4
Conductivity (μmhos)	460	471	470	480
pH (units)	7.8	7.9	7.9	7.9
Alkalinity (mg/l)	131	135	135	138
Total P (mg/l)	0.026	0.027	0.027	0.031
Dissolved P (mg/l)	0.018	0.019	0.019	0.021
NO_2 + NO_3 (mg/l)	0.130	0.141	0.140	0.160
Ammonia (mg/l)	0.210	0.226	0.230	0.230
		ALL VALUES		
Secchi disc (inches)	60	82	72	108

B. Biological characteristics:

1. Phytoplankton* -

Sampling Date	Dominant Genera	Number per ml
09/18/72	1. Fragilaria	1,135
	2. Melosira	961
	3. Anabaena	376
	4. Flagellates	202
	5. Microcystis	103
	Other genera	629
	Total	3,406
11/14/72	1. Melosira	1,092
	2. Fragilaria	678
	3. Synedra	527
	4. Aphanothece	282
	5. Cyclotella	282
	Other genera	1,715
	Total	4,576

* The June sample was lost in shipment.

2. Chlorophyll a -
(Because of instrumentation problems during the 1972 sampling, the following values may be in error by plus or minus 20 percent.)

Sampling Date	Station Number	Chlorophyll a (µg/l)
06/13/72	01	15.5
	02	18.9
	03	14.8
09/18/72	01	6.9
	02	16.0
	03	7.2
11/14/72	01	1.2
	02	1.2
	03	1.2

C. Limiting Nutrient Study:

More than half of the dissolved phosphorus in the algal assay sample was lost between the time of collection and the beginning of the assay, and the results are not representative of conditions in the lake at the time the sample was collected (09/18/72).

The lake data indicate nitrogen limitation in June and September (N/P ratios were 10/1) but phosphorus limitation in November (N/P = 19/1).

IV. NUTRIENT LOADINGS
(See Appendix D for data)

For the determination of nutrient loadings, the Michigan National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the months of April and June, when two samples were collected, and November when samples were omitted. Sampling was begun in October, 1972, and was completed in September, 1973.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Michigan District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for the White River were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loadings for "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated by using the mean concentrations in Cleveland Creek at station B-1 and the mean ZZ flow.

The operation of the Whitehall primary wastewater treatment plant was discontinued in July, 1973, when the Whitehall/Montague land disposal system became operative; however, only two effluent samples were submitted for analysis during the 10-month operating period of the plant. Therefore, the nutrient loads attributed to the Whitehall STP

* See Working Paper No. 1.

were estimated at 2.5 lbs P and 7.5 lbs N/capita/year and were adjusted for the ten months of operation during the sampling year.

The Whitehall Leather Company and Hooker Chemical Company continued discharging to White Lake throughout the sampling year. Reportedly (Robinson, Cosens, & Mills, 1967), the Whitehall Leather Company discharges about three pounds of total phosphorus and 193 pounds of inorganic nitrogen daily, while the Hooker Chemical Company discharges about one pound of total phosphorus per day and essentially no inorganic nitrogen. These values were used to estimate the annual loads from these sources.

A. Waste Sources:

1. Known municipal† -

Name	Pop. Served	Treatment	Mean Flow (mgd)	Receiving Water
Whitehall	3,017*	land disp.	0.431**	None

2. Known industrial*** -

Name	Product	Treatment	Mean Flow (mgd)	Receiving Water
Hooker Chem. Co.	chems.	?	9.200	White Lake
Whitehall Leather Co.	leather	?	1.190	White Lake

* 1970 Census.
** Based on limited flow data provided by operator.
*** Robinson, Cosens, & Mills, 1967.
† Wetzel, 1973.

B. Annual Total Phosphorus Loading - Sampling Year:

1. Inputs -

Source	lbs P/ yr	% of total
a. Tributaries (non-point load) -		
White River	36,520	80.5
b. Minor tributaries & immediate drainage (non-point load) -	480	1.1
c. Known municipal STP's -		
Whitehall (10 mos.)	6,290	13.9
d. Septic tanks* -	230	0.5
e. Known industrial -		
Hooker Chemical Company	360	0.8
Whitehall Leather Company	1,100	2.4
f. Direct precipitation** -	400	0.8
Total	45,380	100.0

2. Outputs -

Lake outlet - White River 35,230

3. Net annual P accumulation - 10,150 pounds

* Estimate based on 375 lakeshore dwellings; see Working Paper No. 1.
** See Working Paper No. 1.

C. Annual Total Nitrogen Loading - Sampling Year:

1. Inputs -

Source	lbs N/ yr	% of total
a. Tributaries (non-point load) -		
White River	851,020	83.7
b. Minor tributaries & immediate drainage (non-point load) -	35,390	6.4
c. Known municipal STP's -		
Whitehall (10 mos.)	18,860	1.5
d. Septic tanks* -	8,810	0.7
e. Known industrial -		
Hooker Chemical Company	-	-
Whitehall Leather Company	70,440	5.7
f. Direct precipitation** -	24,770	2.0
Total	1,009,290	100.0

2. Outputs -

Lake outlet - White River 802,730

3. Net annual N accumulation - 206,560 pounds

* Estimate based on 375 lakeshore dwellings; see Working Paper No. 1.
** See Working Paper No. 1.

D. Mean Annual Non-point Nutrient Export by Subdrainage Area:

Tributary	lbs P/mi^2/yr	lbs N/mi^2/yr
White River	76	1,769

E. Yearly Loading Rates:

In the following table, the existing phosphorus loading rates are compared to those proposed by Vollenweider (in press). Essentially, his "dangerous" rate is the rate at which the receiving waters would become eutrophic or remain eutrophic; his "permissible" rate is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic rate would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with very short hydraulic retention times.

Units	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
lbs/acre/yr	17.7	3.9	392.6	80.3
grams/m^2/yr	1.98	0.44	44.0	9.0

Vollenweider loading rates for phosphorus (g/m^2/yr) based on mean depth and mean hydraulic retention time of White Lake:

"Dangerous" (eutrophic rate)	1.28
"Permissible" (oligotrophic rate)	0.64

V. LITERATURE REVIEWED

Bastian, Robert K., 1974. Personal communication (Muskegon County wastewater management systems). EPA Proj. Support Off., Muskegon.

Ketelle, Martha J., and Paul D. Uttormark, 1971. Problem lakes of the United States. EPA Water Poll. Contr. Res. Ser., Proj. 16010 EHR.

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Vollenweider, Richard A. (in press). Input-output models. Schweiz. Z. Hydrol.

Wetzel, Michael, 1973. Treatment plant questionnaire (Whitehall STP). MI Dept. Nat. Resources, Lansing.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	FALL VALUES MEAN TOTAL P	FALL VALUES MEAN DISS P	FALL VALUES MEAN INORG N	ALL VALUES 500- MEAN SEC	ALL VALUES MEAN CHLORA	ALL VALUES 15- MIN DO
2640	HOLLOWAY RESERVOIR	0.062	0.043	1.461	439.375	10.678	9.200
2641	CARO RESERVOIR	0.117	0.022	3.835	473.000	11.967	9.500
26A2	BOARDMAN HYDRO POND	0.006	0.005	0.358	363.500	1.267	6.600
2603	ALLEGAN LAKE	0.123	0.057	1.168	470.222	20.311	12.600
2606	BARTON LAKE	0.121	0.006	1.489	456.167	27.800	14.650
2609	BELLEVILLE LAKE	0.118	0.048	1.420	465.250	28.262	8.283
2610	BETSIE LAKE	0.025	0.008	0.273	461.667	4.567	7.480
2613	BRIGHTON LAKE	0.109	0.073	1.015	456.000	44.233	7.500
2617	LAKE CHARLEVOIX	0.007	0.006	0.230	351.250	3.000	9.240
2618	LAKE CHEMUNG	0.044	0.014	0.132	484.333	13.483	14.600
2621	CONSTANTINE RESERVOIR	0.027	0.008	0.910	456.167	39.317	7.500
2629	FORD LAKE	0.105	0.058	1.536	456.167	14.733	14.000
2631	FREMONT LAKE	0.372	0.342	1.406	441.667	28.500	14.000
2640	JORDAN LAKE	0.180	0.144	1.990	427.667	20.517	14.900
2643	KENT LAKE	0.040	0.015	0.417	455.000	33.944	13.000
2648	LAKE MACATAWA	0.197	0.120	2.358	477.600	25.680	12.200
2649	MANISTEE LAKE	0.010	0.010	0.304	451.333	6.317	11.360
2659	MUSKEGON LAKE	0.087	0.043	0.469	436.444	9.511	14.600
2665	PENTWATER LAKE	0.027	0.017	0.496	430.667	16.083	14.800
2671	RANDALL LAKE	0.246	0.183	0.810	457.333	27.217	8.020
2672	ROGERS POND	0.026	0.015	0.183	435.500	8.133	9.600
2673	ROSS RESERVOIR	0.034	0.021	0.460	465.333	10.383	8.200
2674	SANFORD LAKE	0.016	0.008	0.307	458.750	13.791	8.300
2683	THORNAPPLE LAKE	0.042	0.032	1.737	442.833	14.650	10.800
2685	UNION LAKE	0.083	0.064	1.252	455.500	15.667	8.200
2688	WHITE LAKE	0.027	0.019	0.367	417.778	9.211	13.400
2691	MONA LAKE	0.307	0.241	0.963	451.667	27.783	14.100
2692	LONG LAKE	0.163	0.148	0.749	418.400	10.867	13.600

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	FALL VALUES: MEAN TOTAL P	FALL VALUES: MEAN DISS P	FALL VALUES: MEAN INORG N	ALL VALUES: 500-MEAN SEC	ALL VALUES: MEAN CHLORA	ALL VALUES: 15-MIN DO
2693	ST LOUIS RESERVOIR	0.134	0.093	1.227	462.667	5.583	8.420
2694	CRYSTAL LAKE	0.009	0.006	0.164	380.000	2.986	13.000
2695	HIGGINS LAKE	0.007	0.005	0.058	268.500	1.843	9.400
2696	HOUGHTON LAKE	0.018	0.008	0.136	420.833	9.217	8.200
2697	THOMPSON LAKE	0.043	0.029	0.436	407.889	11.967	14.800
2698	PERE MARQUETTE LAKE	0.032	0.024	0.346	448.667	11.833	8.600
2699	STRAWBERRY LAKE	0.069	0.050	0.567	419.800	11.117	13.600

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	ALL VALUES: MEAN TOTAL P	ALL VALUES: MEAN DISS P	ALL VALUES: MEAN INORG N	ALL VALUES: SOO- MEAN SEC	ALL VALUES: MEAN CHLOWA	ALL VALUES: 1S- MIN OD	INDEX NO
2640	HOLLOWAY RESERVOIR	46 (16)	43 (15)	17 (6)	57 (20)	60 (21)	63 (22)	266
2641	CARO RESERVOIR	29 (10)	54 (19)	0 (0)	3 (1)	49 (17)	54 (19)	189
2642	BOARDMAN HYDRO POND	97 (34)	97 (34)	69 (24)	91 (32)	94 (33)	97 (34)	549
2643	ALLEGAN LAKE	20 (7)	31 (11)	31 (11)	6 (2)	29 (10)	40 (14)	157
2646	BANTON LAKE	23 (8)	20 (7)	14 (5)	29 (9)	14 (5)	3 (1)	103
2649	BELLEVILLE LAKE	26 (9)	37 (13)	20 (7)	11 (4)	11 (4)	79 (26)	184
2650	BETSIE LAKE	77 (27)	77 (27)	80 (28)	17 (6)	86 (30)	94 (33)	431
2653	BRIGHTON LAKE	31 (11)	23 (8)	34 (12)	34 (12)	0 (0)	90 (31)	212
2657	LAKE CHARLEVOIX	91 (32)	91 (32)	83 (29)	94 (33)	89 (31)	60 (21)	508
2658	LAKE CHEMUNG	49 (17)	71 (25)	94 (33)	86 (30)	46 (16)	11 (2)	357
2661	CONSTANTINE RESERVOIR	71 (25)	83 (29)	40 (14)	29 (9)	3 (1)	90 (31)	316
2669	FORD LAKE	34 (12)	29 (10)	11 (4)	29 (9)	37 (13)	23 (8)	163
2671	FREMONT LAKE	0 (0)	0 (0)	23 (8)	54 (19)	9 (3)	11 (2)	97
2680	JORDAN LAKE	11 (4)	11 (4)	6 (2)	69 (24)	26 (9)	0 (0)	123
2683	KENT LAKE	57 (20)	69 (24)	63 (22)	40 (14)	6 (2)	34 (12)	271
2688	LAKE MACATAWA	9 (3)	14 (5)	3 (1)	0 (0)	23 (8)	43 (15)	92
2689	MANISTEE LAKE	80 (28)	74 (26)	77 (27)	46 (16)	80 (28)	46 (16)	403
2699	MUSKEGON LAKE	37 (13)	40 (14)	54 (19)	60 (21)	69 (24)	11 (2)	271
2705	PENTWATER LAKE	69 (24)	63 (22)	51 (18)	66 (23)	31 (11)	11 (2)	291
2711	RANDALL LAKE	6 (2)	6 (2)	43 (15)	23 (8)	20 (7)	86 (30)	184
2712	ROGERS POND	74 (26)	66 (23)	86 (30)	63 (22)	77 (27)	51 (18)	417
2713	RUSS RESERVOIR	60 (21)	57 (20)	57 (20)	9 (3)	63 (22)	79 (28)	345
2714	SANFORD LAKE	86 (30)	80 (28)	74 (26)	20 (7)	43 (15)	71 (25)	374
2723	THORNAPPLE LAKE	54 (19)	46 (16)	9 (3)	51 (18)	40 (14)	49 (17)	249
2725	UNION LAKE	40 (14)	26 (9)	26 (9)	37 (13)	34 (12)	79 (28)	242
2728	WHITE LAKE	66 (23)	60 (21)	66 (23)	80 (28)	74 (26)	31 (11)	377
2731	MONA LAKE	3 (1)	3 (1)	37 (13)	43 (15)	17 (6)	20 (7)	123
2732	LONG LAKE	14 (5)	9 (3)	46 (16)	77 (27)	66 (23)	27 (9)	239

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	FALL VALUES: MEAN TOTAL P	FALL VALUES: MEAN DISS P	FALL VALUES: MEAN INORG N	ALL VALUES: 500- MEAN SEC	ALL VALUES: MEAN CHLORA	ALL VALUES: 15- MIN DO	INDEX NO
2693	ST LOUIS RESERVOIR	17 (6)	17 (6)	29 (10)	14 (5)	83 (29)	69 (24)	229
2694	CRYSTAL LAKE	89 (31)	89 (31)	89 (31)	89 (31)	91 (32)	36 (12)	483
2695	HIGGINS LAKE	94 (33)	94 (33)	97 (34)	97 (34)	97 (34)	57 (20)	536
2696	HOUGHTON LAKE	83 (29)	86 (30)	91 (32)	71 (25)	71 (25)	79 (26)	481
2697	THOMPSON LAKE	51 (18)	49 (17)	60 (21)	83 (29)	51 (18)	11 (2)	305
2698	PERE MARQUETTE LAKE	63 (22)	51 (18)	71 (25)	49 (17)	54 (19)	66 (23)	354
2699	STRAWBERRY LAKE	43 (15)	34 (12)	49 (17)	74 (26)	57 (20)	27 (9)	284

APPENDIX B

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR MICHIGAN 2/3/75

LAKE CODE 2688 WHITE LAKE

TOTAL DRAINAGE AREA OF LAKE(SQ MI) 509.00

TRIBUTARY	SUB-DRAINAGE AREA(SQ MI)	NORMALIZED FLOWS(CFS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
2688A1	509.00	502.41	502.41	712.25	679.72	623.46	449.95	354.10	359.15	412.62	430.78	533.68	510.48	522.24
2688A2	481.00	472.00	472.00	664.00	627.00	585.00	423.00	333.00	338.00	387.00	405.00	502.00	531.00	495.09
2688ZZ	28.00	26.00	26.00	37.00	45.00	33.00	23.00	16.00	16.00	22.00	22.00	27.00	29.00	27.15

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 509.00
SUM OF SUB-DRAINAGE AREAS = 509.00

TOTAL FLOW IN = 6270.00
TOTAL FLOW OUT = 6271.00

MEAN MONTHLY FLOWS AND DAILY FLOWS(CFS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2688A1	10	72	478.00	29	728.00				
	11	72	497.00						
	12	72	500.00	3	458.00				
	1	73	859.00	7	897.00				
	2	73	523.00	4	807.00				
	3	73	872.00	4	1070.00				
	4	73	760.60	4	839.00	26	836.00		
	5	73	823.00	10	1180.00				
	6	73	542.00	5	749.00	24	442.00		
	7	73	377.00	10	364.00	22	334.00		
	8	73	343.00	25	338.00				
	9	73	322.00	27	334.00				
2688A2	10	72	453.00	29	690.00				
	11	72	471.00						
	12	72	474.00	3	434.00				
	1	73	814.00	7	860.00				
	2	73	541.60	4	765.00				
	3	73	827.00	4	1020.00				
	4	73	720.00	4	795.00	26	794.00		
	5	73	780.00	10	1120.00				
	6	73	551.00	5	710.00	24	419.00		
	7	73	357.00	10	345.00	22	316.00		
	8	73	325.00	25	320.00				
	9	73	305.00	27	316.00				
2688ZZ	10	72	25.00						
	11	72	26.00						
	12	72	26.00						
	1	73	45.00						
	2	73	32.00						
	3	73	45.00						
	4	73	46.00						
	5	73	43.00						
	6	73	31.00						
	7	73	20.00						
	8	73	18.00						
	9	73	17.00						

APPENDIX C

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 75/02/04

260801
43 24 00.0 086 21 30.0
WHITE LAKE
26 MICHIGAN

11EPALES 2111202
5 0020 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/06/13	16 35	0000	19.4	10.7	60	500	8.50	147	0.050	0.110	0.044	0.031
	16 35	0015	18.3	9.8		500	8.55	147	0.040	0.060	0.027	0.017
72/09/18	15 05	0000			60	400	8.90	129	0.070	0.090	0.025	0.016
	15 05	0004	21.2	10.4		400	8.90	128	0.060	0.060	0.025	0.012
	15 05	0015	19.6	7.2		380	8.30	134	0.140	0.190	0.030	0.014
72/11/14	11 10	0000			108	480	7.90	136	0.160	0.220	0.028	0.020
	11 10	0004	6.9	10.2		480	7.90	136	0.160	0.230	0.027	0.021
	11 10	0015	6.9	10.4		480	7.90	135	0.150	0.220	0.028	0.021
	11 10	0021	6.9	10.2		480	7.90	134	0.150	0.210	0.031	0.020

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/13	16 35	0000	15.5J
72/09/18	15 05	0000	5.9J
72/11/14	11 10	0000	1.2J

J VALUE KNOWN TO BE [illegible]

STORET RETRIEVAL DATE 75/02/04

268802
43 22 30.0 085 25 00.0
WHITE LAKE
26 MICHIGAN

11EPALES 2111202
5 0040 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/06/13	17 00	0000	18.3	9.6	90	470	8.55	146	0.070	0.090	0.023	0.015
	17 00	0015	17.6	9.7		420	8.55	146	0.050	0.080	0.017	0.010
	17 00	0030	12.3	6.3		440	8.10	140	0.120	0.220	0.020	0.016
72/09/18	15 45	0000			72	400	8.90	128	0.020	0.040	0.021	0.013
	15 45	0004	19.3	9.4		400	8.90	128	0.020	0.030	0.019	0.012
	15 45	0015	19.1	8.0		410	8.70	128	0.030	0.050	0.021	0.012
	15 45	0020	19.0	7.6		420	8.65	127	0.030	0.070	0.020	0.011
	15 45	0026	18.9	7.4		400	8.60	125	0.040	0.100	0.022	0.014
	15 45	0033	17.3	2.2		430	7.95	126	0.070	0.410	0.064	0.051
	15 45	0040	16.5	2.8		400	8.00	126	0.070	0.370	0.057	0.047
	15 45	0047	16.4	1.6		425	7.90	126	0.070	0.430	0.097	0.061
72/11/14	10 20	0000			108	470	7.90	133	0.140	0.230	0.026	0.019
	10 20	0004	7.0	10.4		470	7.90	135	0.140	0.230	0.027	0.018
	10 20	0015	7.0	10.4		470	7.90	135	0.140	0.220	0.028	0.018
	10 20	0025	7.0	10.3		470	7.90	136	0.140	0.220	0.028	0.018
	10 20	0040	7.0	10.3		480	7.90	138	0.140	0.230	0.026	0.020
	10 20	0054	6.9	10.4		480	7.90	138	0.140	0.230	0.028	0.018

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/13	17 00	0000	18.9J
72/09/18	15 45	0000	15.0J
72/11/14	10 20	0000	1.2J

J VALUE KNOWN TO BE [illegible]

STORET RETRIEVAL DATE 75/02/04

23<

268803
43 23 00.0 086 22 00.0
WHITE LAKE
26 MICHIGAN

11EPALES
5

2111202
0025 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/06/13	17 40	0000	19.4	10.5	72	440	8.60	145	0.040	0.060	0.028	0.016
	17 40	0015	16.8	8.9		460	8.50	145	0.060	0.110	0.022	0.015
72/09/18	15 25	0000			72	415	8.83	124	0.040	0.050	0.020	0.012
	15 25	0004	19.9	9.3		405	8.85	125	0.040	0.050	0.024	0.012
	15 25	0015	19.1	7.5		410	8.60	125	0.060	0.110	0.025	0.013
	15 25	0020	18.9	7.3		430	8.55	125	0.040	0.110	0.025	0.015
	15 25	0027	18.2	3.9		420	8.10	124	0.050	0.280	0.052	0.030
	15 25	0034	17.4	3.7		420	8.10	124	0.050	0.300	0.050	0.031
72/11/14	10 50	0000			108	460	7.80	133	0.130	0.230	0.026	0.019
	10 50	0004	7.1	10.4		460	7.90	133	0.130	0.230	0.027	0.018
	10 50	0015	7.1	10.4		460	7.90	132	0.130	0.230	0.028	0.020
	10 50	0020	7.1	10.4		460	7.90	131	0.130	0.230	0.026	0.019

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/13	17 40	0000	14.8J
72/09/18	15 25	0000	7.2J
72/11/14	10 50	0000	1.2J

J VALUE KNOWN TO BE IN ERRO-

APPENDIX D

TRIBUTARY and WASTEWATER TREATMENT PLANT DATA

STORET RETRIEVAL DATE 75/02/04

2688A1 LS2688A1
43 22 30.0 086 25 30.0
WHITE RIVER
26 15 MONTAGUE
U/WHITE RIVER
SAMPLE OUTLT CHANL N EDGE OF WABANINGO
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29			0.130	0.500	0.176	0.016	0.035
72/12/03	10 45		0.270	0.850	0.075	0.011	0.024
73/01/07	15 30		0.310	0.960	0.086	0.011	0.025
73/02/04	10 45		0.330	0.330	0.072	0.016	0.030
73/04/04	18 10		0.231	0.540	0.126	0.005K	0.030
73/04/26	07 45		0.105	0.540	0.014	0.005K	0.020
73/05/10	09 15		0.147	0.540	0.017	0.005K	0.035
73/06/05	18 20		0.056	0.480	0.039	0.006	0.030
73/06/24	13 10		0.023	0.460	0.028	0.010	0.030
73/07/10	14 30		0.040	0.800	0.066	0.012	0.050
73/07/22	07 00		0.017	1.050	0.009	0.012	0.060
73/08/25	10 00		0.084	0.580	0.011	0.009	0.035
73/09/27	18 30		0.105	0.640	0.080	0.009	0.040

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/04

2688A2 LS2688A2
43 25 30.0 086 19 30.0
WHITE RIVER
26 15 MONTAGUE
1/WHITE LAKE
BRDG ON US31 NE WHITEHALL
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29	11 05		0.068	1.600	0.160	0.012	0.029
72/12/03	10 00		0.280	0.910	0.078	0.011	0.018
73/01/07	15 00		0.260	0.630	0.027	0.010	0.022
73/02/04	10 15		0.320	0.310	0.024	0.010	0.030
73/03/04	09 40		0.399	0.500	0.052	0.014	0.035
73/04/04	17 30		0.063	0.420	0.046	0.010	0.025
73/04/26	06 00		0.025	0.880	0.048	0.011	0.025
73/05/10	08 45		0.022	0.700	0.044	0.012	0.035
73/06/05	19 25		0.080	0.600	0.042	0.027	0.060
73/06/24	11 50		0.010K	0.500	0.036	0.032	0.077
73/07/10	12 00		0.168	0.340	0.034	0.018	0.050
73/07/22	07 30		0.093	1.980	0.198	0.016	0.030
73/08/25	10 15		0.168	0.390	0.032	0.022	0.045
73/09/27	17 30		0.105	0.340	0.089	0.016	0.040

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/04

2688A3 LS2688A3
43 28 00.0 086 14 00.0
WHITE RIVER
26 15 TWIN LAKE
T/WHITE LAKE
CO RD BRDG 1 MI NW BIG BLUELAKE
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29	10 30		0.117	1.600	0.105	0.012	0.028
72/12/03	09 35		0.280	0.360	0.026	0.010	0.017
73/01/07	14 30		0.300	0.990	0.056	0.011	0.021
73/02/04	09 45		0.340	0.440	0.063	0.012	0.025
73/03/04	09 15		0.490	0.800	0.138	0.020	0.060
73/04/04	17 25		0.176	0.340	0.036	0.009	0.020
73/04/26	08 45		0.098	0.600	0.025	0.016	0.040
73/05/10	08 00		0.100	0.320	0.058	0.018	0.047
73/06/05	18 55		0.176	0.520	0.032	0.027	0.065
73/06/24	12 10		0.240	0.520	0.046	0.030	0.075
73/07/10	12 35		0.189	1.980	0.084	0.015	0.050
73/07/22	07 45		0.120	1.380	0.050	0.012	0.030
73/08/25	10 30		0.220	0.460	0.026	0.019	0.050
73/09/27	17 10		0.110	0.210	0.038	0.010	0.025

STONET RETRIEVAL DATE 75/02/04

208801 LS268881
43 26 30.0 086 14 00.0
CLEVELAND CREEK
26 15 TWIN LAKE
T/WHITE LAKE
CO RD BRDG 4 MI N OF LAKEWOOD
MEPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29	10 40		0.087	1.650	0.120	0.005K	0.007
72/12/03	09 30		0.020	2.000	0.667	0.005K	0.009
73/01/07	14 30		0.072	0.540	0.032	0.005K	0.004
73/02/04	09 15		0.026	0.100K	0.015	0.005K	0.005K
73/03/04	08 45		0.035	0.190	0.029	0.006	0.010
73/04/04	17 20		0.019	0.100K	0.014	0.005K	0.010
73/04/26	08 30		0.010K	0.240	0.011	0.005K	0.005K
73/05/10	07 30		0.013	1.150	0.018	0.005K	0.015
73/06/05	19 10		0.013	0.650	0.017	0.005K	0.015
73/06/24	12 20		0.015	0.520	0.022	0.005K	0.010
73/07/10	12 50		0.014	0.230	0.028	0.005K	0.010
73/07/22	08 00		0.034	0.770	0.032		0.005K
73/08/25	10 50		0.010K	0.340	0.024	0.008	0.010
73/09/27	17 00		0.023	0.330	0.054	0.006	0.010

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/04

268850 PR268850 P003017
43 25 00.0 086 26 00.0
WHITEHALL
26 15 MONTAGUE
U/WHITE LAKE
WHITE LAKE
LIEPALES
4 2141204
0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
73/02/12	00 00								
CP(T)-			2.750	19.000	0.880	2.700	7.300	0.478	0.456
73/02/12	08 00								
73/03/27	09 00								
CP(T)-			1.200	15.400	0.098	4.500	6.400	0.483	0.406
73/03/27	16 00								